# The Geology of North Mountain, Cape Breton

BY

T. D. Guernsey

L. G.

STANFORD UNIVERSITY LIBRARY
MAR 24 1930

SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE DEGREE OF DOCTOR OF PHILOSOPHY,
IN THE FACULTY OF PURE SCIENCE,
OF COLUMBIA UNIVERSITY

CONTRIBUTIONS FROM THE DEPARTMENT OF GEOLOGY OF COLUMBIA UNIVERSITY, VOLUME XL, No. 2

*Reprinted from Summary Report, 1927, Part C,*
*Geological Survey, Canada*

3781
C72G
UNCLASSED
Dissertation

STANFORD UNIVERSITY LIBRARIES
WITHDRAWN

# THE GEOLOGY OF NORTH MOUNTAIN, CAPE BRETON

*By T. D. Guernsey*

CONTENTS


| | Page |
|---|---|
| Introduction | 1 |
| General character of the district | 2 |
| General geology | 4 |
| Physiography | 23 |
| Mineral resources | 31 |


Illustration


Map 2177. 223A. North Mountain area, Inverness county, N.S. ..... In pocket


## INTRODUCTION

North mountain lies about 10 miles northeast of the strait of Canso and borders the northwest shore of West bay, one of the arms of Bras d'Or lake. The mountain is roughly 15 miles long and 3½ to 4 miles wide. The Canadian National railway skirts the northwest flank and the area is readily accessible from three stations on this railway; namely, West Bay Road, River Denys, and Orangedale.

Field work was carried on during the summer of 1926. The writer was assisted by R. M. Williams. Mr. W. A. Bell and Mr. M. E. Wilson of the Geological Survey visited the writer in the field.


Their advice and helpful criticisms are gratefully acknowledged. Special thanks are due to the many residents of the district who in so many ways facilitated the progress of the field work.

This report was prepared under the guidance of the Department of Geology, Columbia University. The writer gratefully acknowledges the friendly counsel and advice received from the late Professor J. F. Kemp, Professor C. P. Berkey, Professor D. W. Johnson, and Professor R. J. Colony.


The mountain is formed of pre-Carboniferous rocks and there is a pronounced topographic boundary between the area occupied by these rocks and that underlain by the Carboniferous strata that flank the mountain. Rock outcrops are fairly abundant on the mountain in the immediate vicinity of streams, but away from the streams, exposures, except in special cases, are rare and, generally, small.

The many records of Cape Breton geology contain few references to North mountain. Sir William Dawson, in his classical work, "Acadian Geology", mentioned

> "The syenite and porphyry extensively developed . . . in the irregular tract at the sources of the Inhabitants river and River Denys."[1]

Prior to the year 1855, the Reverend David Honeyman noted the occurrence of marble on North mountain,[2] and commencing in 1875 the reports

[1] Dawson, J. W.: "Acadian Geology"; 1st Edition, Edinburgh, 1855, 384 pp., p. 323.

[2] Honeyman, D.: "Record of Observations on Nova Scotian Geology Since 1855"; N.S. Inst. Nat. Sc., Pr. Tr. 3, pp. 6-18, 18-40 (1873-74).

of the Nova Scotia Department of Mines record a lime-burning industry at Marble Mountain.

The geologic surveys of the eastern part of Nova Scotia, commenced by Charles Robb and completed by Hugh Fletcher, covered the whole of Cape Breton island. Fletcher's report on the counties of Richmond, Inverness, Guysborough, and Antigonish, published in the Report of Progress for 1879-80, contains the only systematic work relating to the geology of North mountain. Fletcher mapped the crystalline rocks, and, following a classification made in an area farther to the east, divided them into two groups, Carboniferous and Precambrian. He divided Precambrian into the George River Limestone, and a group defined as consisting of syenitic, gneissoid, and other feldspathic rocks. Fletcher believed the George River limestone to be unconformable upon the underlying igneous rocks.

This early work was summarized by Young[1] in 1913 in a description of the type locality of the George River limestone.

The following quotation shows some divergence from Fletcher's interpretation.

"Recent examinations made of some typical sections of the George River series indicate, however, that the granites unmistakably cut and are younger than the George River series. The correlation on lithologic grounds of the George River series with the Laurentian (Grenville-Hastings) of distant Quebec is perhaps no longer justifiable. But the various points of resemblance existing between the Precambrian of Cape Breton and the original Laurentian, are worthy of note."[2]

It follows, therefore, that one of the major problems to be determined in this re-examination of the ground was that of the true structural relations of the principal formations.

## GENERAL CHARACTER OF THE DISTRICT

### TOPOGRAPHY

Cape Breton is characterized by a series of upland areas separated by broad lowland valleys, or by the arms of Bras d'Or lake. According to Goldthwait[3] the uplands are remnants of an extensive plain, once lying nearly at sea-level and resulting from the long-continued action of subaerial erosive processes. Movement of a regional nature lifted the plain above sea-level and tilted it to the south, so that today at cape North, the most northerly point in Cape Breton, the ancient plain stands at an altitude of about 1,200 feet above sea-level, whereas at Madame island, to the south, the plain disappears beneath the Atlantic ocean. Since the time of uplift, erosion has etched the broad lowland valleys out of the softer rocks, leaving the more resistant rocks as upland ridges. The western part of the island contains four such ridges, not all of the same size, but preserving the same general trend, and characterized by a remarkable evenness of the summits.

[1] Young, G. A.: "George River"; 12th Int. Geol. Cong., Guide Book 1, pt. II, pp. 266-276 (1913).
[2] Young, G. A.: Op. cit., p. 267.
[3] Goldthwait, J. W.: "Physiography of Nova Scotia"; Geol. Surv., Canada, Mem. 140, 179 pp., p. 4 (1924).

North mountain is the second largest of the four uplands in western Cape Breton. It rises about 700 feet above West bay which flanks it on the southeast and is an arm of Bras d'Or lake whose surface is at sea-level. The lowland to the north and northwest is occupied by a partly drowned river valley known as Denys basin and by the basins of two rivers, known as Denys river and Inhabitants river.

The mountain is about 15 miles long, $3\frac{1}{2}$ miles to 4 miles broad, and extends northeast-southwest. It rises abruptly from the lowland areas, the northwest and southeast slopes being fairly steep. The northeastern end is slightly lower than the central part; at the southwestern end, in the vicinity of West Bay Road, the relative elevation of the upland is not nearly so pronounced because the bordering lowland there also attains an appreciable elevation. The top of the mountain is nearly flat, with a gentle, downward inclination to the northwest, and the transition from the flat top to the steep slopes is abrupt.

The drainage of the mountain is mainly to the northwest by several large and numerous smaller streams flowing in valleys cut deeply into the resistant rocks. A number of the streams rise in small, shallow, swamp-fringed lakes. The gradients of the northward-flowing streams are, as a rule, uniform, although falls occur on several of the streams close to where they issue from the highland. The southward flowing drainage is relatively short and is characterized by the steepness of the stream gradients. In most instances the valleys have not been cut back to the headwaters of the streams, which in their upper courses flow over the upland through swampy, poorly drained areas, many of which are, doubtless, ancient lakes that have become filled through the growth of vegetation. In many of the southward-flowing streams the change in gradient at the scarp of the mountain is pronounced. They are at first sluggish and deep, flowing through a succession of swampy areas, but on nearing the south scarp the gradient increases and the waters finally plunge downward by a series of cataracts. At the eastern end of the mountain the even contour of the upland is broken by two embayments of the lowland, one of which projects east along the valleys of McKenzie brook and the other west along a brook flowing into Little harbour. The valleys of these two streams unite at their heads to form a notch.

The lowlands are rolling and are well drained by streams that have cut wide valleys into the general lowland level. Denys river, the master stream of the lowland to the north, rises in Craignish hills, another upland ridge about 10 miles northwest of North mountain. Big brook, flowing along the northwest base of North mountain, is an important tributary to Denys river.

Small alluvial fans are numerous along the base of the upland and are especially noticeable in the valley of Big brook. They are built up at the mouths of the deep upland valleys where the decreased gradient on the lowland permits only the finer material to be carried by stream currents.

West bay and Denys basin are arms of Bras d'Or lake. The water is saline and supports a marine fauna, but the tides, of only a few inches, are variable, and are considerably affected by winds. Denys basin is

shallow with a narrow, tortuous entrance and is now seldom used by vessels of deep draught. West bay is navigable for vessels of all draughts.

### POPULATION AND INDUSTRIES

The population of the district is mainly of the descendants of Scotch settlers who came to Cape Breton during the first half of the nineteenth century. Gaelic is spoken by many and is still the only tongue of a few. A few Indian families are resident at a government reserve on Malagawatchkt peninsula.

Farming is the chief industry; hay, oats, potatoes, and vegetables being the common crops. At one or two places on the south side of the mountain, small fruits, especially strawberries, are grown to advantage. Although the best farms are on the lowlands, the northeast, southeast, and southwest slopes of the mountain are cultivated to some extent, although at the present time not all of the holdings are occupied. Fishing, though important, does not reach the status of an industry. A few oysters and lobsters are exported and a considerable number of codfish are taken and dried for local use. Previous to the year 1922 the Dominion Iron and Steel Company worked an extensive limestone quarry at Marble Mountain. The abandonment of the quarry, which employed several hundred men, removed an important economic industry from the community.

Where not farmed, the country is covered with a thick growth of hardwoods and conifers. These are mainly of second growth, as a violent gale in August, 1873, destroyed a large part of the timber standing at that time. The trees grow to good size on the well-drained slopes, but the swampy, poorly drained areas on the top of the mountain support only a stunted growth of conifers. The soft woods are cut in a small way for lumber to be used locally, and as pitprops for the coal mines. When market conditions are favourable, considerable spruce is cut and exported as pulpwood to the United States.

Four villages are included in the area of the map sheet. They are: River Denys, West Bay Road, West Bay, and Marble Mountain. River Denys and West Bay Road are each about 8 miles from the Victoria highway, the main automobile road through Cape Breton. The road encircling North mountain is suitable for automobile traffic, but the roads across the mountain have difficult grades and are seldom used.

## GENERAL GEOLOGY

### OUTLINE

The rock formations of North mountain are readily grouped into three main divisions, namely:

(1) A complex, pre-Carboniferous basement.

(2) A thick series of Carboniferous sediments which rest with marked unconformity upon the older basement.

(3) Unconsolidated material of glacial and fluviatile origin.

The pre-Carboniferous basement consists of ancient sedimentary and volcanic rocks that have been intruded and metamorphosed by granite. Granite makes up the greater part of North mountain, whereas the intruded group occurs as a rather narrow belt serving to divide the granitic mass into two nearly equal areas.

The Carboniferous sediments rest upon an erosion surface carved on the pre-Carboniferous complex. For the most part the Carboniferous sediments occupy the valley lowlands. Their upturned edges were noted along the lower slopes of North mountain.

Glacial debris lies upon the surface of all the preceding formations and in the valleys is augmented by stratified sands, gravels, and clays.

*Table of Formations*

| | | |
|---|---|---|
| Quaternary | | Boulder clay, sand, gravel, and clay |
| Palæozoic | Pennsylvanian (?) | Sandstone and shale |
| | Mississippian: Windsor series | Conglomerate, limestone, gypsum, shale |
| Pre-Mississippian, probably Precambrian | Igneous intrusives | Basic and acid dykes |
| | | Granite, and, or, granodiorite |
| | George River series | Volcanics, quartzite, limestone, greywacke |

GEORGE RIVER SERIES

The primary classification of the Precambrian rocks in Cape Breton was accomplished during the study of the Boisdale hills, an area lying south of St. Andrew channel.[1]

The rocks were divided into two main groups. The lower group was described under the heading, "Syenitic,[2] gneissoid, and other feldspathic rocks," and the upper group under the name "George River Crystalline Limestone series." The George River series was believed to be younger than, and to rest unconformably upon, the underlying igneous rocks. Although the original work of Fletcher, and later that of Matthew,[3] and others, has demonstrated that both groups are undoubtedly Precambrian, later work on sections of the George River series has shown that the igneous rocks are intrusive into the sediments, and that the sediments are, therefore, the older of the two groups.

The name George River is taken from a small stream of that name which flows along the trend of the Boisdale hills, and enters St. Andrew channel near its northeastern extremity. The name as applied to the older sedimentary rocks in this vicinity was first used by the Reverend David

[1] Fletcher, H.: "Report on Explorations and Surveys in Cape Breton, Nova Scotia"; Geol. Surv., Canada, Rept. of Prog. 1875–76, pp. 369–418.

[2] The word syenite, as used in early reports, indicated a rock composed principally of feldspar, hornblende, and quartz.

[3] Matthew, G. F.: "Report on the Cambrian Rocks of Cape Breton"; Geol. Surv.. Canada, Pub. No. 797, 1903, 246 pp.

Honeyman in 1873,[1] although the strata were not described in detail until 1876 when Fletcher published his report on this district. In its typical development the George River series is described as consisting of

"highly crystalline limestone and dolomite, containing talc, mica, tremolite, plumbago, galena, hematite, magnetite, and other minerals, interstratified with felsite, syenite, diorite, mica schist, quartzite, and quartzose conglomerate; and dipping steeply to the south of east."[2]

No fossils are known to occur in this series and the exact succession of the strata is somewhat in doubt, but from sections described by Robb,[3] the limestones are apparently interbedded with the quartzose strata which grade up into shales.

The descriptions of the rocks lying below the George River series indicate that they are mainly plutonic, but include "laminated felsites" which are apparently to be differentiated from both the George River series and the intrusive rocks. Speaking of the felsites as found in Craignish hills, Fletcher states:

"The distribution of the . . . felsites here lends strength to the assumption that they belong to the syenite series and are older than the crystalline series which appears at no great distance from them and distinctly overlies the syenite into which these felsites insensibly merge."[4]

Describing the George River series as found on North mountain, Fletcher refers to the felsites as follows:

"The opinion already expressed that this (George River series) forms an overlying unconformable group of Precambrian age is greatly strengthened by the results of recent investigations, the limestones in every case capping the felsites, with which, however, they often seem to blend near the contacts as if by a common metamorphism. . . . That the felsites were subsequently intruded or contemporaneous volcanic deposits seems less probable."[4]

Gilpin, in 1886, summarized this problem in a paper delivered to the Geological Society.

"Two divisions have been recognized in these measures. The lower consists of laminated felsites and interstratified porphyry and syenite and gneissoid rocks; the upper is characterized by the addition of great beds of limestone. Mr. Fletcher, speaking of the lower division, gives it as a result of his experience that both the felsite and syenite strata are intimately associated as part of the same group of crystalline rocks, differing not so much in composition as in the degree of crystallization they have been subjected to, and that as no evidence has been found proving the higher position of the felsites, they may at present be considered together."[5]

The present writer recognized volcanic rocks on North mountain. They are poorly developed and not distinctly separable from the sedimentary George River strata. In spite of the fact that Fletcher reported a conglomerate or breccia containing fragments of felsite within the George River series in the type area, the writer is inclined to interpret the felsites as a part of the George River series which, for the North Mountain district, thus is made to include all sedimentary and associated rocks that have been intruded by granite.

---

[1] Honeyman, D.: "Notes on the Geology of Nova Scotia and Cape Breton"; N.S. Inst. Nat. Sc., Pr. Tr. III, pp. 193–202, p. 196 (1871–74).

[2] Fletcher, H.: Op. cit., p. 382.

[3] Robb, C.: "Report on Explorations and Surveys in Cape Breton, Nova Scotia"; Geol. Surv., Canada, Rept. of Prog. 1874–75, pp. 166–266, pp. 252–257.

[4] Fletcher, H.: "Report on Surveys in Richmond, Inverness, Guysborough, and Antigonish Counties, Nova Scotia"; Geol. Surv., Canada, Rept. of Prog. 1879–80, pt. F, 125 pp., p. 12 F.

[5] Gilpin, E.: "The Geology of Cape Breton Island, Nova Scotia"; Quart. Jour. Geol. Soc., vol. 42, pp. 515–526, p. 516 (1886).

On North mountain the George River series has its chief development in a band that extends southwest along the south scarp of the mountain from Little Harbour to Lime Hill and from there westward across the mountain to River Denys.

Owing to the complexity of this group, and insufficient exposures, the relations between its several members are not well known. The members are described in the following order, namely: Volcanic member, Limestone member, Quartzite-greywacke member.

*Volcanic Member*

The volcanics are believed to be the oldest rocks exposed, and do not appear to be of very great extent. They may be seen to good advantage on the bare hill northwest of Little Harbour, locally known as "The Creigan", and they extend southwestward along the scarp of the mountain towards the head of Mill brook. No exposures of them were recognized between Mill brook and Lime Hill, but in the vicinity of Mill brook and inland similar rocks are strongly developed.

The volcanic rocks are generally soft, fine-grained, and dark green. Their exact nature, even under the microscope, is obscure, for the primary minerals have been converted into aggregates and pseudomorphs of amphibole, chlorite, carbonate, sericite, epidote, magnetite, and leucoxene. The feldspars, when discernible as such, are lath-shaped and have, apparently, small extinction angles.

Trachytic, porphyritic, and amygdaloidal structures were noted. Interstitial quartz is present in some specimens and small veinlets of carbonate cut the rocks. Staining by ferric oxide is very common.

At 'The Creigan' the rock carries specks of sulphite and close jointing is very prominent. What was taken to be pillow structure was observed on the weathered surface. The pillows are rather small, 1 foot to 18 inches long, and although not conspicuous, were accentuated by small arcuate areas that weather a lighter colour than the surrounding surfaces.

Near Lime Hill the rocks are massive and dense, with much ferric iron on the weathered surface. Pillow structures were not noted in this vicinity; the rocks are arranged in rude sheets, 15 to 20 feet thick and with a very steep dip.

*Limestone Member*

The limestones of the George River series may be traced in more or less isolated exposures over the entire length of the sedimentary belt. The best development is in the vicinity of Marble Mountain, between the village and Little Harbour, and northeast of Campbell brook in the southern part of the belt where it crosses the mountain.

The limestones are invariably crystalline and commonly of coarse texture, but where metamorphism is apparently at a minimum the texture is fine and banding prominent. They may be grey or white on the fresh surface, but weather bluish. Granite intrudes the limestones and the effects produced include the formation of ophicalcites, dolomitic limestone, white massive marble, and occasionally the development of quartz, lime silicates, and abundant pale yellow mica. The intrusive nature of the

granite is very plain along the top of the south scarp of the mountain from the lakes at the head of Mill brook, westward to, and beyond, Sydenham brook. In this area there are many exposures of the limestones which so far as could be determined are wholly surrounded by granite. A contact between granite and limestone is visible on the Marble Mountain-Munroe Bridge road, and west of Sydenham brook the granite was observed to include blocks of limestone 4 to 6 feet long. At these points few structures are to be seen in the limestone which is white, coarse, and contains a considerable proportion of magnesium.

The relatively numerous exposures of the limestones may possibly give a false impression of their extent and thickness, for it is probable that they are to some extent interbedded with the quartzites and greywackes to be described next.

*Quartzite-Greywacke Member*

Quartzites outcrop at several places along the sedimentary belt. A very good section of these rocks is to be seen in the valley of Mill brook, and they may be traced southwestward along the scarp of the mountain where small exposures of limestone and quartzite are associated with granite. A considerable thickness is also exposed below the road at Marble Mountain. Near River Denys, the quartzites again appear. Lithologically the rocks range from a micaceous arkose to a nearly pure quartzite; a micaceous quartzite is the most common facies. They are thoroughly recrystallized and it is only occasionally that the original grain outlines can be distinguished.

The quartzites at Mill brook are mainly dark grey, well-banded rocks of fine grain. Under the microscope they are seen to be largely composed of quartz, with usually a strong development of biotite. Subordinate white mica is present and occasionally altered feldspar occurs as scattered grains or in distinct bands. Light green amphiboles in small, fresh, hypidiomorphic prisms, are very common in some specimens, with occasionally larger, incomplete crystals enclosing original quartz grains. Two of the slides examined contain small grains of unknown minerals of high relief. These grains are somewhat elongated, but rounded, and have pitted surfaces. They occur scattered amongst the quartz and biotite, or distributed along the foliation in lines. In the latter case they appear in greatest quantity with bands of altered feldspar. The most common of these undetermined minerals is analogous to zircon and the group as a whole is believed to be heavy minerals of the original sediment.

Quartzite is in contact with limestone in the quarry at Marble Mountain. It weathers rather dark red due to small flakes of hematite and abundant staining with ferric oxide. Below the limestone the first rock noted is an almost pure white quartzite, but as the exposures are traced towards the shore, biotite becomes more prominent and forms distinct bands, 1 to 4 millimetres thick. Ferric oxide along the banding gives a dark colour to the exposures.

Quartzites occur on the northwest slope of the mountain near River Denys. The rock outcropping nearest to the limestones of this locality is a red-weathering, well-banded arkose, but within 150 feet this gives place to an almost pure white quartzite.

At the shore, southwest of Little Harbour, and again in the valleys of Dallas and Campbell brooks, the rocks outcropping on the south side of the limestone zone differ markedly from any already described. They are dark, fine-grained, impure grits and greywackes, which by shearing pass into slates and schists. Banding is noticeable at some localities and where the rocks are least disturbed bedding is more or less prominent. Under the microscope quartz is seen to be the dominant mineral. It occurs in single and composite grains ranging in size from microscopic fragments up to grains $\frac{3}{4}$ of a millimetre in diameter; and it is accompanied by a few scattered grains of feldspar and occasionally a lithic fragment. Sericite is present in varying quantity and is associated with chlorite and small fragments of ferromagnesian minerals. Banding is not prominent in the thin sections examined and most commonly the quartz grains are scattered heterogeneously through the finer groundmass. They are equidimensional, but are not especially rounded, nor were they noted to be drawn out or sheared.

In the upper valley of Campbell brook the rocks are slates and shales, with some few thin beds of limestone. Extremely schistose graphitic shales occur a short distance below the upper forks and are again exposed above the bridge on the southeast branch. All the beds in this vicinity dip very steeply to the south and in the northern exposures they are much contorted. The beds are cut by veinlets of carbonate and quartz, the latter carrying iron and copper sulphides. These same conditions prevail along the road to Lime Hill and in the valley of Dallas brook. Here, however, limestone is exposed in greater quantity, is banded, contorted, and at places contains serpentinous material and brown mica. Judging from scattered outcrops the greatest width was between 250 and 300 feet.

Near the mouth of Dallas brook the rocks are much crumpled, although the original bedding can still be distinguished. Proceeding northeastward, between Lime Hill and Marble Mountain, two small quarries above the road again show limestone in contact with strata of the quartzite-greywacke member, which, in general, are schistose. At several outcrops along the shore, one or two thin beds of quartzite, and a thin bed of conglomerate or breccia were observed. Where schistose the rocks are very soft, chloritic, and hold lenses and stringers of carbonate.

The exposures farther northeast where the pre-Carboniferous rocks come to the shore to the southwest of Little Harbour, show the strata to be well bedded, very compact, and of extremely fine grain. Their stratigraphic position relative to neighbouring bodies of the limestone is indeterminable because of close folding and faulting. At one place, graphitic shales apparently underlie a well-bedded limestone.

The strata of the band of George River series are characterized by a general southwesterly strike. The dips are almost invariably steep, from 50 to 70 degrees, and close folding is pronounced at some localities. Conditions are such that the stratigraphical succession within the George River series has not been established. The limestone member forms a valuable key horizon, but its worth is somewhat impaired by the possibility of overturned folds. The volcanic rocks are thought to form the

base of the series on North mountain. They are mainly developed near the contact with the granite and only sparsely elsewhere. Their relations with the other members of the series are not established, but the presence of a volcanic rock interbedded with the micaceous quartzites at Mill brook, suggests that the quartzites succeed the volcanic member. The association of the micaceous quartzites with the limestones, and the limestones with the greywackes, also suggests that the limestones are an intermediate member separating the two quartzose formations. The possibility that the micaceous quartzites are, in part, metamorphosed equivalents of the greywackes, does not affect this conception.

The succession then as tentatively set forth, is, from the base upwards: (1) volcanics; (2) quartzites with a zone of thick, interbedded limestone, and, grading up into; (3) greywackes.

## IGNEOUS INTRUSIVES

### *Granite*

Igneous rocks, mainly granitic in character, occupy the greater part of North mountain. As already stated, the granite is intrusive into the George River strata. It is not practicable to draw a sharp line of contact between the two groups, as they are generally mixed within an intervening zone of greater or less width. Variations in the character of the granite occur in many places between successive outcrops and there is a possibility that the granite is the result not of one intrusion but of a series of intrusions, although no evidence to this effect was obtained.

Typically the granite is pink, or grey, depending on the proportions of flesh-coloured and white feldspars. The texture varies from medium to coarse, but the grain is seldom even, being commonly hiatal and occasionally porphyritic. In some cases the grains range up to, and exceed, one centimetre in greatest dimension.

The rocks as indicated by the examination of thin sections, vary from a true granite to a quartz diorite, with granodiorite as perhaps the most common facies. Some doubt is felt as to whether the more basic examples are truly representative of any large mass of the rock, as it is thought that scattered inclusions of the sediments may occur more abundantly than were noted and thus cause rapid changes in composition.

In the slides examined the primary essential minerals, in order of abundance, are: feldspars, quartz, biotite, and, in some cases, hornblende. The proportions are, approximately: feldspars 50 per cent, quartz 40 per cent, biotite 10 per cent. The accessory minerals include: magnetite, ilmenite, apatite, zircon, and titanite.

The feldspars are chiefly plagioclases, but orthoclase, perthite, and microcline are not uncommon. The plagioclases show alteration, but appear to range between oligoclase and andesine. The orthoclase is also altered, but the microcline and perthite are commonly comparatively fresh. Sericite is the principal alteration product of the feldspars, but epidote is present as stringers and patches in the more altered individuals. Unaltered feldspar of a more acid type was noted to occur along the edges of, and in some instances to penetrate, the altered crystals. The quartz forms coarse

aggregates. The quartz individuals in some cases hold small crystals of feldspar, or penetrate or cut the feldspar clusters, or occur as small, rounded grains within crystals of feldspar. The quartz aggregates are crossed by lines of inclusions, and strain shadows are prominent in most of the slides examined.

The biotite is developed in small crystals that are inclined to be grouped. In some sections the biotite shows only slight alteration around the edges, but in others it is almost completely destroyed.

Green hornblende is present in some of the sections. Like the biotite it is developed in comparatively small crystals and shows only slight alteration.

The accessory minerals are not abundant. The iron ores are in greatest quantity and occur mostly with the ferromagnesian minerals. Zircon and apatite appear as inclusions in both the biotite and hornblende. Titanite was noted in only one section.

### INTRUSIVE AND CONTACT PHENOMENA

Although mixed zones of the granite and George River strata are most strongly developed as a fringe bordering the sedimentary strata, there are areas removed from the sedimentary belt where inclusions of the sediments occur in the igneous rocks. Because of the limited number of exposures, the delimitation of the borders of the mixed zones, and especially of those removed from the main belt of sediments, could only be roughly approximated. Over most of the area, weathering of the granites does not appear to be deep, and characteristically the feldspars decay leaving the quartz aggregates projecting as knobby protuberances from the surface. In the western part of the area, and especially in the valley of the west fork of McLeod brook, the weathering is very deep and a fresh surface was unobtainable from any outcrop. The stream has cut a narrow gorge in the granite, from 10 to 30 feet deep, and from caves in the side of the gorge the rock may be scraped off with the bare hand.

Between Marble Mountain and Little Harbour, where volcanic rocks occur along the western edge of the band of George River strata and, therefore, are believed to be in direct contact with the granite, the granite of the intervening mixed zone is characterized by the presence of oval bodies. These are commonly not more than 3 or 4 feet long and may be as small as 8 inches. They are arranged with their long axes paralleling the length of North mountain, that is paralleling the structural trend of the district, and the line of contact. On the weathered surface they are easily distinguished by their colour which is slightly darker than that of the normal granite, but on fresh surfaces they are not clearly defined.

The rock of these oval bodies when examined under the microscope is seen to be of medium grain and to consist of plagioclase, biotite, hornblende, and quartz in the proportions of about 4-2-2-2. The accessory minerals include apatite, magnetite, and a little titanite. The plagioclases have an index which is slightly lower than the index of balsam and, from determination made on the twinning lamellæ, the composition is between oligoclase and andesine. The biotite and hornblende are closely

associated and in some cases are intergrown. Both show varying degrees of alteration to chlorite, and a little zoisite may also be present. The hornblende is light green, strongly pleochroic, and contains scattered patches of needle-like inclusions, probably rutile. The dark brown biotite is characterized by alteration products, occurring as lenticular masses between the folia, and for the most part appearing to be colourless epidote. The quartz occurs in very irregular shapes between the feldspars and generally exhibits rectilinear boundaries. It is unevenly distributed and in several cases a number of adjacent areas were noted to have the same optical orientation. It is evident that this rock differs from the granitic rocks in being more basic, and in carrying a higher proportion of hornblende, but it has no structures that seem to indicate that it has been derived from any part of the George River series.

Quartz-poor igneous rocks were noted on the road a few hundred yards east of Mill brook. They outcrop close to the sedimentary rocks, and are much darker than the typical granitic rocks. An abrupt variation from medium to coarse texture was observed in adjoining outcrops. In mineralogy and structure the medium-grained phase is somewhat similar to the rock of the oval bodies described above. The coarse variety is characterized by brown hornblende and large aggregates of secondary chlorite, leucoxene, epidote, and zoisite. Quartz is subordinate and interstitial, is much fractured, and carries radiating aggregates of a colourless mineral with the optical properties of epidote.

At Marble Mountain where the granite is in contact with limestones and quartzites, oval bodies such as those already described were not noted, but instead the passage from the granite area of the band of George River strata consists of an alteration of bands and patches of sediment and granite. In places the mixed zone is of considerable width. It extends southwest along the scarp of the mountain towards the lake at the head of Sydenham brook, and where it is crossed by the Marble Mountain-Munroe bridge road the limestone, occurring within 10 feet of granite outcrop, is characterized by the differential weathering of metamorphic minerals developed along the bedding planes. The granite is not greatly affected close to the contact, although a slight decrease in the intensity of the colour is apparent and the texture is somewhat finer. At Sydenham brook the limestone, which, so far as could be seen, is entirely surrounded by granite, does not show the development of contact minerals, nor is banding present on the weathered surface. Near the scarp of the mountain the granite was observed to carry blocks of the limestone. The feldspars of the granite lack colour and are inclined to be idiomorphic and zonal. Quartz is present in some quantity and exhibits penetration effects against the feldspars, as well as slight evidences of straining. The rock shows only slight alteration.

Still farther southwest, in the neighbourhood of Lime Hill and in the valley of Campbell brook, the mixed zone on the whole is narrow. That part on the farm of Mr. Neil McMillan, on the Lime Hill-River Denys road, shows granitic rocks in close proximity to limestones and quartzites. Here the sedimentary rocks appear to be more profoundly affected than those observed farther east.

Four isolated mixed zones are shown on the accompanying map. Two at the northeastern end of the mountain are small and exhibit only slight evidences of the older rocks. The two larger areas near the southwestern end of the mountain contain a variety of rock types, and although remnants of the sedimentary rocks appear to be present in only small quantity, they are widely spread, and are believed to have exerted a profound influence on the character of the intrusive. Since the rocks in these two areas differ somewhat in general appearance, they will be described separately and in some detail.

### *The Lime Hill-Ross Brook Mixed Zone*

The rocks of this zone are best seen in the valleys of Ross and McCuish brooks, and along the shoreline, where, although outcrops are few, the beach is made up of large boulders showing most of the rock types noted on the hillslope above.

The most abundant general rock type, called "diorite" in the field, shows gradations from granite to quartz-bearing gabbro. This general type is invariably grey, but the shade varies with the grain size and the content of ferromagnesian minerals, both of which are subject to rapid change. The texture is commonly equi-granular, but in places is slightly porphyritic. The variations exhibited by this general type are indicated by the following descriptions.

The rocks east of McCuish brook, near the road, are of variable grain size and various shades of grey. The dominant mineral is acid feldspar, mainly orthoclase, but with some acid plagioclase. Green hornblende is the most important constituent after feldspar.

Biotite occurs rather sparingly as a primary constituent. It is associated with the hornblende. A little quartz occurs interstitially and replaces the feldspar in part. Apatite, magnetite, and titanite are the accessory minerals.

The rock outcrop along the road between Ross and McCuish brooks is very dark, coarse, and consists mainly of hornblende in short, thick prisms. Feldspar and quartz are also present, and with the hornblende occur in the proportions of about 5-2-2. Pyroxene, magnetite, pyrite, titanite, epidote, and apatite make up the remainder. The hornblende, feldspar, and quartz act as hosts to each other and to the remaining constituents. The hornblende is brown and green, both varieties being noted in the same crystal. Some of the smaller grains are associated with a pale green pyroxene, close to diopside, and probably resulted from the alteration of that mineral. The feldspars are mainly untwinned plagioclases, with distinct zonal structures and between oligoclase and andesine in composition. The quartz occurs in rather large, irregular grains and exhibits more pronounced poikilitic structures than do the other minerals. Some of the grains show slight strain shadows.

A specimen from the small stream east of McCuish brook is from a locality where the granite apparently grades into the type under discussion. This specimen has a faintly developed porphyritic structure. The constituents in order of abundance are: feldspars, quartz, hornblende, and biotite, in the proportions of about 5-2-1-1. Magnetite, titanite, and

apatite are the accessory minerals. The feldspars are plagioclases, about andesine in composition, with distinct zonal structures. The hornblende is green. Brownish yellow biotite is associated with the hornblende.

Another example from the small stream east of McCuish brook is one of the darkest specimens of this general type. It is of medium grain and consists of labradorite, quartz, and alteration products in the proportions of about 5-3-2. The quartz does not appear to be primary, for although in considerable quantity in the slide, it is in largest part restricted to one rather large, lens-shaped area. Smaller interstitial patches of quartz show myrmekitic intergrowths with the plagioclase.

A variety from the east branch of McCuish brook is a medium-grained rock whose essential constituents are acid feldspar, and altered ferromagnesian mineral, and quartz, in the proportions of about 5-3-2. The structure is slightly porphyritic and there is a slight but obscure banding on a large scale. The feldspar appears to be dominantly orthoclase, with some little acid plagioclase. The ferromagnesian minerals are totally replaced by chlorite, leucoxene, a little feldspar, carbonate, and epidote, the original mineral is believed to have been biotite.

Another example from the east branch of McCuish brook is a medium-grained, grey rock, consisting of quartz, feldspar, hornblende, and biotite in the proportions of about 5-3-1-1. The quartz occurs in quite large grains which surround and enclose the feldspars. The feldspars are chiefly acid andesine, but also include a more acid plagioclase and a few comparatively large crystals of orthoclase. Some of the plagioclases are zonal. The hornblende is green and occurs in long, irregular prisms. It is associated with a little granular epidote, probably an alteration product. The biotite is in part an alteration product from the hornblende, but some of it is primary.

Associated with the above described rocks are others of widely different character. These include limestones, gneisses, and dark, coarse, badly altered granitic rocks. Dykes of aplitic character cut all the other rock types and in some places are very numerous.

The limestones occur abundantly in the lower part of Ross brook and were observed in rather thin bands in the upper part of McCuish brook, where they are somewhat crumpled. Although preserving their identity, they are much metamorphosed and exhibit pronounced differential weathering. Besides calcite, the chief constituents are micas, olivine, and serpentinous material, which combine to give the rock a grey colour. The micas are colourless and unaltered. They are grouped in aggregates of rounded grains. The serpentinous material is variable in amount. It occurs in more or less rounded aggregates believed to be pseudomorphic after the olivine.

The gneisses occur mainly along the north edge of the mixed zone. Good exposures may also be seen in the two small streams west of Dallas brook. Variations in the general appearance and in the amount of banding exhibited were taken to indicate that probably both orthogneisses and injection gneisses were present.

Rock classified as orthogneiss was found not far west of Lime Hill. It is of granitic habit and the foliation, due to the ferromagnesian minerals,

is rather coarse and interrupted. The principal constituents are quartz, acid feldspar, and biotite. The feldspars include orthoclase, acid plagioclase, microcline, and perthite.

The most common gneiss is a grey, medium-grained rock with a well-developed, rather fine foliation. The feldspars, in about equal proportions with quartz, include orthoclase, perthite, microcline, and a little plagioclase. Biotite is the principal ferromagnesian mineral and is developed in large crystals. Pale brown aggregates of secondary minerals are concentrated near the biotites. They consist of serpentinous material, pale green amphibole, colourless micas, ferric iron, and a little titanite. They are thought to be derived from olivine. Inclusions of zircon are present in the aggregates.

All the rocks of the above assemblage are cut and injected by small dykes and stringers of aplite. In places these are very numerous and they are especially abundant on the east branch of McCuish brook. In general the walls of the stringers where they cut the granitic rocks are not well defined, and there is a gradation from the light-coloured aplite to the darker enclosing granitic rock.

The aplite consists of orthoclase, microcline, perthite, and a little albite. Interstitial quartz is present in some specimens, but as a rule the rocks appear to be poor in this mineral. Ferromagnesian minerals are not present in any quantity, and in some examples are entirely lacking.

An example of a rock formed by lit-par-lit injection was found on the west branch of McCuish brook. This rock is darker and of finer grain than the gneisses described above. The different bands are 4 to 5 millimetres wide. The primary rock is foliated along planes parallel to the layers of injected material and consists of quartz grains set in an extremely fine, complex mass of alteration products, including colourless micas, leucoxene, carbonate, pyroxenes, saussurite, zoisite, and magnetite. In addition there are many elongated grains of rutile scattered along the foliation and large, clear grains of a colourless pyroxene form a distinct but thin band. The injected material consists of microcline, microperthite, pale brown biotite, and scattered grains of pyrite. The contact between the primary and injected material is zonal and the feldspars along the contact hold the original minerals in poikilitic structures. Shreds of pale green pyroxene, and a little carbonate are scattered through the feldspars and are evidently derived from the primary rock.

### *The West Bay Road-Big Brook Mixed Zone*

This zone differs from the above described zone on the southwest side of the mountain, in that inclusions are more numerous within the igneous rocks, and the intruded sediments are recognizable at only a few places. The streams between Big Brook post office and West Bay Road afford the best opportunities for observing the rocks in this zone. Good exposures may also be seen along the road going southward across the mountain from Big Brook post office.

The most common type of rock is somewhat similar in mineralogy and structure to the grey granites, etc., of the Lime Hill-Ross Brook mixed zone. Here, however, the rocks are coarser and in places grade

into types very similar to, and in some instances more acid than, the granitic rocks. With the distinctly igneous rocks are darker rocks showing rapid variations in texture. Where the road going southward from Big Brook post office approaches the south boundary of the mixed zone as drawn on the map, the rocks along the road include fine-grained granite, gneissic granite, medium-grained diorite, and a coarse blotchy rock of dominant green colour. These same conditions prevail in some of the stream courses where dark, greenish, schistose rocks contain varying amounts of injected igneous material. Commonly the rock consists of a few irregular, pink feldspars in a dark groundmass. Inclusions are not discernible, and in general the rocks appear very similar to the nebulites of Sederholm[1] and Weinschenk.[2] At some places the greenish rocks contain no injected material, and in these cases are seen to be dark rocks with greenish feldspars and much chloritic mica. In places they are very schistose. All gradations of mixing between these rocks and the granites are to be seen, and the dark rocks may predominate over the granite in the proportion of about three to one.

Gneisses are commonly associated and intermixed with the dark rocks. From their appearance they are all injection gneisses and may be fine- or coarse-grained with varying degrees of banding. One specimen in thin section is seen to be a medium-grained rock consisting of quartz, andesine, and ferromagnesian minerals in the proportions of about 6-2-2. The ferromagnesian minerals are mainly green hornblende and biotite, but a colourless pyroxene is present in small quantity and is the mineral from which the hornblende is derived. The hornblende is arranged in aggregates of grains that contain many, small, irregular, and rounded inclusions of some colourless mineral, probably a feldspar. Intergrowths of feldspar with hornblende or pyroxene lie along the boundaries of many of the aggregates. The biotite is a very deep brown, and commonly holds large grains of magnetite. Rounded grains of quartz and feldspar are very prominent in one part of the thin section. The grains are very dusty and are enclosed and held in larger crystals of quartz.

Where distinct and recognizable xenoliths appear in the igneous rocks the latter are even-grained, but the shade of colour varies with the locality. Xenoliths are fairly numerous throughout the mixed zone, but are seen to best advantage along the roads crossing the mountain, where they are common in the igneous rocks, in this case granites.

The xenoliths are not large and are invariably rounded. They are darker and of finer grain than the enclosing rock, and are quite prominent even on fresh surfaces. In some cases they have a porphyritic structure, which is blasto-porphyritic, the blastocrysts being feldspars derived from the enclosing rock. The borders of the xenoliths in many cases contain abundant blastocrysts with a flecked appearance due to the inclusion of minerals from the xenolithic rock. The border blastocrysts are at times extensions of crystals from the coarse-grained granitic host.

---

[1] Sederholm, J. J.: "On Migmatites and Associated Pre-Cambrian Rocks of Southwestern Finland"; part 1, "The Pellinge Region". Bull. de la Comm. Geol. de Finlande, 58, 153 pp., p. 120 (1923).

[2] Weinschenk, E.: "The Fundamental Principles of Petrology". Tr. A. Johannsen, McGraw-Hill, New York, 1916, 214 pp., p. 65.

A xenolith in the vicinity of the first stream east of West Bay Road is a rather fine-grained rock showing pink and green coloration. Microscopic examination shows that the rock is composed of dominant quartz occurring in small, rounded grains with some larger aggregates, and grains of very cloudy orthoclase. Between the grains is much dusty material, principally chlorite, sericite, leucoxene, carbonate, epidote, and finely divided quartz. Apatite prisms are present in the quartz grains and the orthoclase owes its cloudy appearance to iron oxide and vermicular chlorite. Slight shearing is noticeable in the thin section. Xenoliths occurring on the road going southward from Big Brook post office are medium-grained, acid rocks of orthophyric structure. They consist chiefly of orthoclase, with a little acid plagioclase, hornblende, and biotite. The feldspars are very much sericitized and are zonal with more or less unaltered feldspar around the edges. The hornblende occurs in elongated prisms. The biotite has been completely altered to chlorite. A little interstitial quartz is present, and magnetite and apatite are distributed through the section.

The host rock is a coarse-grained granite consisting of orthoclase, perthite, acid plagioclase, abundant quartz, and subordinate biotite and hornblende. The action of the granite on the xenolith may be seen at the boundary between the two where the larger feldspars of the granite penetrate into the xenolith and hold all the constituents in poikilitic structures. The feldspars of the granite show only slight alteration. Although they do not appear to actively corrode the xenolithic minerals, in one case small prisms of sericitized feldspar are present and in another the xenolithic feldspars are absent and only the ferromagnesian minerals remain.

Exposures of recognizable sediments are few. Small exposures of metamorphic limestone, associated with dark quartzose rocks, were noted at two places. The limestones are finer in grain than are the rocks on the south side of the mountain, and hold abundant pale mica, garnets, quartz, and occasionally graphite, and traces of iron and copper sulphides.

In some localities small quartz veins are numerous, but are not persistent. They appear cutting the above described rocks. Where the quartz parallels the foliation of the rock the original minerals have been profoundly altered, and a thin section shows interrupted bands of alteration aggregates in clear granular quartz.

### *Minor Intrusives*

A number of dykes of varying composition cut the granite and members of the George River series.

The extent and persistence of the dykes are not known, for, although twenty exposures were noted, in no case was it possible to trace any one dyke for any distance along the strike. Mineralogically they may be divided into three groups: basic, intermediate, and acid.

The basic dykes are the largest and also probably the most numerous. They appear to be developed in two sets, striking on the average 58 degrees and 152 degrees (true). The widths range from 20 inches up to, in one case, 70 feet. Most are diabasic and some are slightly porphyritic. They consist of basic andesine, or labradorite, monoclinic pyroxene, and, in some

cases, biotite. The accessory constituents include magnetite, ilmenite, pyrite, and apatite. In most specimens examined the feldspars occur in idiomorphic or hypidiomorphic prisms with the pyroxene as interstitial filling. Some show a distinct zonal structure. The pyroxenes and biotite are much altered, and in some cases completely destroyed. Hornblende is a common alteration product, and is accompanied by aggregates of chlorite, epidote, carbonate, and leucoxene. Quartz was observed in a few specimens. It is small in amount and occurs interstitially with intimate penetration effects against, and in one case intergrowths with, the feldspars.

The largest basic dyke noted, outcrops on the Marble Mountain-Munroes Bridge road. It is a hornblende diorite, of coarse, granular texture, and consists of andesine and hornblende in the proportion of about 6, -3, accompanied by white mica and alteration products of sericite, fibrous hornblende, chlorite, and leucoxene.

Dykes of intermediate composition were noted at four exposures. Of these, one is referable to as bostonite, the others are lamprophyric in character. The bostonite is fine-grained, porphyritic, and consists mainly of acid feldspars heavily stained with iron oxide. Carlsbad twinning is present in the phenocrysts, but the feldspar rods of the groundmass exhibit little twinning of any character. No distinct ferromagnesian minerals are present, but the groundmass contains chlorite, sericite, and a little epidote, much of which is associated with the feldspars. The lamprophyres are porphyritic and approach vogesites in character. The dominant mineral is acid feldspar, probably almost wholly orthoclase. Pyroxene and biotite are present in some specimens, but not in great quantity. Quartz is generally subordinate and interstitial, but in one specimen made up about one-third of the rock and was intimately intergrown with the feldspars. The feldspars of the groundmass carry abundant ferric iron dust and are altered to a considerable extent to sericite, and are penetrated by mats of fresh, green, actinolite rods. The alteration of the ferromagnesian minerals produces fibrous amphibole, micas, chlorite, leucoxene, carbonate, sericite, and epidote which generally appear as pseudomorphic aggregates after the ferromagnesian phenocrysts. Zircon, magnetite, and in some cases titanite, occur as accessory minerals.

The strictly acid dykes, excepting the aplites of the Lime Hill-Ross Brook mixed zone, appear to be rather few. They include granophyres and coarse rocks of granitic character that in places are porphyritic. Ferromagnesian minerals are subordinate and where noted consist mainly of a little bleached biotite. Only one dyke of pegmatitic character was noted. It occurs in the stream east of McCuish brook, and is a coarse rock made up of quartz, feldspar, and a little green mica. The quartz is concentrated along the middle of the dyke, whereas the feldspar occurs along the walls. The mica projects from the walls into the feldspar.

### CARBONIFEROUS

The lowlands surrounding North mountain are developed on Carboniferous rocks. In the vicinity of the mountain the Carboniferous beds for the most part are Mississippian and belong, largely, to the Windsor

series. Younger measures, of Pennsylvanian age, occur to the southwest, on the hill northwest of Big brook and in the valley of Inhabitants river.

The lowest exposed Carboniferous beds are conglomerates and rest on eroded surfaces of the crystalline rocks. The conglomerates are made up in greatest part of fragments from the underlying rocks, cemented by carbonate and finely comminuted material from the same rocks. All the pebbles are angular, with rounded edges, and, although in places the largest are about 2 inches in diameter, the usual size is less than 1 inch. The character of the conglomerate depends upon the neighbouring older rocks. Where these are the George River series, the pebbles are of limestone, schist, greywacke, and gneiss, mixed with small fragments of quartz and feldspar. Where granite is the underlying rock, the conglomerate is a coarse arkose barely distinguishable from the weathered rock beneath and the cement is dark green, limy material. Small, grey or grey-green lenses of sand are common even in the lowest part of the conglomerate and in some places carry obscure plant remains.

Exposures of conglomerate were observed at six widely spaced points around the base of the mountain. At no place did the exposed thickness exceed 15 feet, and at only one point were overlying strata seen in contact with the conglomerate.

In the valley of Campbell brook, a short distance below the lower forks, are isolated exposures of conglomerate which, so far as could be determined, are in place. This occurrence is well within the area of North mountain where the valley sides rise steeply for several hundred feet. Lower down the valley, near its mouth, large, detached blocks of grey conglomerate occur on the hillside northeast of the brook. An outcrop of conglomerate occurs in McKenzie Brook valley well within the area of North mountain, on the south side along the main tributary brook from the south. These conglomerates are possibly of pre-Windsor, Horton age. They are so situated as to indicate that Campbell Brook and McKenzie Brook valleys originated in early Mississippian time when North mountain must have been an upland area.

On the lowland northeast of the mountain in the general vicinity of Little Harbour and Big Harbour and on the bordering lowland on the northwest side from Denys basin inland to River Denys station, gypsiferous Windsor strata apparently closely adjoin the outer edge of the area of Precambrian rocks of North mountain and, in part, make their presence known by areas of low, swampy ground close to the abrupt slope of the mountain. Exposures of the rocks associated with the gypsum are not abundant, but dark, fetid, cavernous limestones, and buff, dolomitic limestones were noted at one or two places. On the hillside above the post office at Big Harbour, a dark, oolitic limestone, carrying micro-fossils, rests on granite with only a few inches of mixed granitic material and lime at the base. As exposed it is about 12 feet thick. This rock is undoubtedly a member of the Windsor series.[1] On the northwest side of the mountain, at the foot of the slope north of the mouth of McKenzie brook, fossiliferous limestone outcrops. This limestone, as stated in a succeeding paragraph, is of lower Windsor age.

[1] Bell, W. A.: Personal communication.

On the southeast side of the mountain, Windsor strata in two places are to be seen lying on Precambrian rocks. At one locality, on the shore southwest from the entrance to Little harbour, fossiliferous, massive, grey limestone dips away from the mountain at an angle of 76 degrees and is separated from the Precambrian by a thin conglomerate. The second locality is a rocky point near the post office at Marshes where a dark, fine-grained, thin-bedded, fossiliferous limestone dips away from the mountain at an angle of 70 degrees and is underlain by conglomerate resting on Precambrian granite.

W. A. Bell, while visiting the writer in the field, made small collections of fossils from the above-mentioned limestones. Mr. Bell makes the following statements in regard to these rocks:

"The conglomerate, and the overlying limestone and gypsum are all referable to the Windsor series, as the limestone from Marshes post office yielded a small Windsor fauna that included *Leptodesma borealis* Beede, and *Pteronites gayensis* Dawson, two characteristic lower Windsor pelecypods. The limestones associated with the gypsum near the mouth of McKenzie brook yielded abundant specimens of *Cranaena*, of a species common in Lower Windsor strata of the type locality at Windsor, as well as specimens of *Dielasma davidsoni* (Hall and Clarke)."

The Carboniferous rocks at the southwestern end of North mountain are quite different from the strata to the northeast. In McLeod brook, dark, fine-grained limestones and limy shales strike about east and dip north at high angles. In Cameron brook, to the south, buff, grey, and green sandstones, in beds from 1 to 2 feet thick, overlie dark, thin-bedded shales carrying a fauna of ostracods and a species of *Leaia*. The sandstones are fine-grained, and carry abundant white mica. Ripple-marked surfaces were noted on loose blocks. The road between West Bay and West Bay Road, although rising to an elevation of about 300 feet, nevertheless runs wholly over Carboniferous rocks, which consist of chocolate and grey shales, and shaly sandstones, dipping southerly. The dip increases as the base of the mountain is approached, except in the vicinity of the road over the mountain to Big Brook where grey shales dip 10 degrees south. They are crumpled, contorted, broken by small faults, and show incipient slaty cleavage. The lithology of the above rocks, as well as their contained fauna, correlate them with some part of the Riversdale series of lower Pennsylvanian age.

The attitude of the formations, in the immediate vicinity of their contact with the older rocks, varies considerably. On the southeast side of the mountain, with the exception of the strata in the embayment at Little Harbour, the dips are very steep, in the neighbourhood of 70 degrees, and are in marked contrast with those on the northwest side of the mountain where the steepest dip noted was 28 degrees. Away from the base of the mountain the formations as a whole appear to be only gently inclined, and strata with low dips may be seen in the valley of Cameron brook, and in the neighbourhood of Denys basin.

The Carboniferous formations dip away on all sides of the pre-Carboniferous basement exposed in North mountain. Originally laid down with perhaps slight initial dips, and derived in largest part from the underlying rocks, they are now characterized by variable and in places very steep dips. Structures similar to these exist on the south side of Craignish

hills to the northwest and probably prevail also on the north side of Sporting mountain to the south.

The lowlands, then, represent structural basins lying between the older uplands. The synclinal nature of the structure is well shown on the hill northwest of Big brook where, as shown on Fletcher's map, the higher formations of the Carboniferous strata dip inwards on all sides of the hill. Although synclinal in general, the structures are not simple, as at many places on the lowland the strata are steeply folded.

Faulting was noted at several points within the pre-Carboniferous crystalline area. At McMillan's farm, on the Lime Hill-River Denys road, a basic dyke, striking about 70 degrees (true), has been displaced in a northerly direction by several closely spaced faults. In the first stream east of West Bay Road, another basic dyke has been involved in fault movement, and the granitic rocks which it cuts are brecciated and contain small fragments of the dyke. This fault appears to parallel the dyke which strikes 70 degrees (true).

Faults along the base of the mountain were observed near the mouth of McKenzie brook, near the cliffs southwest of Little Harbour, between Marble Mountain and Lime Hill, and in the lower part of the east branch of McLeod brook. The faults near McKenzie brook and Little Harbour dip outwards from the crystalline rocks, whereas the other two dip steeply inward. The fault between Marble Mountain and Lime Hill is a strike fault in the George River series.

The maps that accompany Fletcher's report on the western part of Cape Breton,[1] show a large fault along the southwest base of North mountain, close to the contact of the Carboniferous sediments with the older rocks. Undoubtedly this fault was determined from stratigraphic data obtained in the study of the sedimentary rocks of the lowlands southwest of North mountain, as well as by the attitude of the rocks in the vicinity of their contact with the pre-Carboniferous. The direct evidences of faulting along the south and southwest base of North mountain are the above-mentioned faults at Little Harbour, between Marble Mountain and Lime Hill, and in the valley of McLeod brook. The steep, almost vertical, attitude of the Carboniferous rocks in the immediate vicinity of their contact with the older complex is probably also indicative of faulting, but the total evidence appears rather insufficient to assign a major fault to the southeast base of the mountain.

The steep folding of the Carboniferous sediments, and at least some of the faulting along the base of the mountain, are probably referable to the movements that marked the close of the Palæozoic era.

### PLEISTOCENE

The evidence of glaciation on North mountain consists of a mantle of glacial drift which, except in special cases, is rather thin. The drift, in largest part, consists of crystalline boulders mainly granitic, with only a slight admixture of Carboniferous sediments. Towards the western end

[1] Maps numbered 18, 19, 21, 22.

of the mountain the latter become more prominent. A typical boulder clay does not appear to be present on the mountain itself, but is the principal formation making up the islands of West bay.

The thickness of the drift on the top of the mountain is not great, and in many places it is entirely lacking, although a covering of moss and humus obscures the bedrock. This is well instanced along the roads that cross the mountain. These are not especially graded, yet traffic exposes areas of bare rock that in ordinary circumstances would be quite abnormal.

Although rounded surfaces of rock are not uncommon, in only one instance was anything resembling a glacial striation seen. This occurs on an exposure at McMillan's farm close to the road from Lime Hill to River Denys. The orientation of this mark was 135 degrees (true).

The rounded surfaces of the granitic rocks, even where covered with moss, are quite rough, and a thin veneer of cream-coloured, gritty material was commonly observed to lie between the moss and the solid granite. The roughness is due to the quartz grains which stand out on the surface as a result of decay or solution of the feldspars. When liberated from the parent rock these grains accumulate at the bottom of the outcrop as a coarse siliceous sand.

In the main, glacial action appears to have removed all the products of subaerial weathering, leaving the exposed surfaces in a fairly fresh condition. The deeply weathered zone in the western part of the mountain is restricted almost entirely to the west branch of McLeod brook.

On approaching the lowland from the crystalline area, the drift cover increases and, as seen in numerous road cuts, becomes sorted to a considerable extent. In places this sorted material may exceed the unsorted drift. Both are composed of essentially the same materials, namely; rounded boulders, pebbles, and sand of igneous rocks, mixed with fragments and particles of chocolate-coloured shale and sandstone. The colours are almost invariably shades of red, depending on the proportion of igneous material.

The sorted drift is developed to a considerable extent on the lowland to the west of Big Harbour, and in the valley of Big brook. A section exposed at the former place shows a 4-foot band of horizontally stratified, fine, brown sand, overlain by rather coarse gravel. In the valley of Big brook, sections cut by the stream consist of chocolate-coloured clays and sands, interstratified with coarse gravels. The clays are generally in beds from 1 to 3 inches thick, and rarely $\frac{1}{4}$ to $\frac{1}{2}$ inch. Fragments of wood and branches of trees are visible in some of the layers.

Near River Denys and again at West Bay Road, deposits of stratified gravel have been opened and used for railway ballast. At River Denys the deposit is at least 60 feet thick. It consists of a top layer of unstratified material a few feet in thickness, followed below by layers of gravel and coarse sand dipping steeply to the north and east. The deposit projects from the mouth of the valley of Campbell brook, and is apparently an outwash deposit built by that stream. At the present time the brook has cut deeply into the gravels and flows eastward from the mouth of the valley. The writer was informed by employees of the railway, who were working in the gravel pit, that shells were occasionally

found in the basal layers when the deposit was being actively worked. The top of the deposit has an elevation of about 130 feet above sea-level.

The gravels at West Bay Road, which is about 9 miles west of River Denys, have an exposed thickness of 70 feet. These beds also dip to the north and east and the top of the deposit has an elevation of over 250 feet.

The glacial desposits on the southwest side of the mountain are mainly boulder clays, built into oval, elongated hills with a rounded profile. They cover a large part of the lowland southwest of Big Harbour, and make up the irregular peninsulas and islands along the shore as far southwest as the village of West Bay. The hills apparently have their steepest major-axial slope to the east, although in most cases this feature was obscured by wave erosion. The orientation of the hills is variable through an arc of about 90 degrees, but the greater number have an elongation in a direction east of north.

Vigorous wave erosion on the ends and flanks of the hills and islands is exposing the contents to view, and building spits and bars from the eroded material. The hill at the base of Malagawatchkt point has been half cut away along its major axis, exposing a high, steep bank on the south side, and leaving a gentle, forested slope to the north. Magnus island, near the village of West Bay, has been almost entirely cut away, but its former extent may be seen by shoal water to the east of the island.

Of the materials making up the boulder clay the larger boulders are dominantly crystalline with only a few examples of sedimentary rock. The latter, however, increase in the smaller sizes, and the clayey matrix is generally brown or chocolate coloured. Striated boulders are common, and several small, striated pebbles of Carboniferous sandstone were collected from points about 30 feet above water-level on the end of George island.

Evidences of bedrock were obtained at only a few places within the area covered by the oval hills. On Militia peninsula a small outcrop of Carboniferous limestone was observed on the shore not far south of the entrance to Little Harbour, and an area of sink-holes, with limestone boulders, in the interior of the peninsula, was taken to indicate gypsiferous strata. Some of the islands show rather large blocks of gypsum projecting from the boulder clay near the water-level, but in no case was the gypsum actually determined to be in place.

There appears to be little doubt, from the shape, structure, and composition of these hills that they are drumlins, built up from material carried by glacial ice. The possibility that the gypsiferous rocks, observed on some of the islands, may actually be in place, does not materially affect the classification, as the gypsum occurs near the water-level and the wave erosion demonstrates that the greater part of the hills is of glacial origin.

## PHYSIOGRAPHY

The physiographic features of Nova Scotia have been described at some length by several writers, notably R. A. Daly,[1] J. W. Goldthwait,[2] and D. W. Johnson.[3] In its broadest features the province may be

[1] Daly, R. A.: "The Physiography of Acadia"; Harvard Univ. Mus. Comp. Zool., Bull. 38, No. 3, pp. 73-103 (1901).
[2] Goldthwait, J. W.: "Physiography of Nova Scotia"; Geol. Surv., Canada, Mem. 140, 159 pp. (1924).
[3] Johnson, D. W.: "The New England-Acadian Shoreline"; J. Wiley and Sons, N.Y., 1925, 608 pp.

separated into two main divisions, an upland division, and a lowland division.

The upland division, called by Goldthwait, the 'Atlantic Upland'[1] forms the largest physiographic feature, and occupies all the southern half of the province, with extensions and detached areas to the north. It is underlain by resistant rocks of Devonian or pre-Devonian age, and is characterized by a surface of striking uniformity which bevels or cuts across the complex structure of the underlying rocks. Because of this feature it is believed to have originated through long-continued erosion that reduced a mountainous region to a plain.

At the present time the upland emerges from the Atlantic ocean along the southeast coast of Nova Scotia, and rises in altitude as it is traced northwest. The present tilted attitude of the surface is thought to be due to a general warping of the whole region, after erosion had produced a plain near sea-level.

The lowland areas have their chief development towards the northern part of the province, and are underlain by relatively soft rocks mainly of Carboniferous age. The lowlands are more or less deeply sunk below the uplands and owe their existence to erosion which followed the general upwarping of the whole region.

Both the Atlantic upland and the lowland areas are well developed in Cape Breton. The upland appears wherever the hard crystalline rocks come to the surface, and consists of a series of elongated irregular belts that trend northeast from the strait of Canso. The lowlands are the deep, wide valleys that separate the upland belts. They have been eroded principally in the areas of Carboniferous sediments.

In North Mountain district erosion surfaces of different ages are visible or indicated. The oldest are of early Carboniferous age and developed on the crystalline rocks; a younger surface truncates the Carboniferous sediments and the oldest erosion surface or surfaces; and the youngest is developed almost wholly on the Carboniferous sediments.

The Carboniferous sediments of Nova Scotia are dominantly of non-marine character, and are lenticular in nature with lateral gradation in many places. These and other factors demonstrate that parts of the region were in a state of movement, either positive or negative, during the whole period of sedimentation. In Cape Breton the base of the Carboniferous is a thick conglomerate series, which is well developed in the eastern part of the island and is of the age of the Horton series of the mainland.[2] This Horton assemblage occurs in the vicinity of Whycocomagh, at the eastern end of Craignish hills to the north of North mountain, and on Madame island to the south. The nature of the Horton strata and their relations to the older rocks indicate that the pre-Windsor topography consisted of valleys separated by areas of high land. Presumably North mountain was one of these areas of high land. The patch of Carboniferous conglomerate situated towards the centre of the mountain, on the relatively deep floor of Campbell brook, is evidence that at the time of deposition

[1] Goldthwait, J. W.: Op. cit., p. 4.

[2] For the data relating to the Carboniferous sedimentation in Nova Scotia and Cape Breton the writer is indebted to Mr. W. A. Bell of the Geological Survey.

of the conglomerate, the area had very considerable relief. This conglomerate may be of Horton age and possibly, therefore, by Windsor time continued erosion of the uplands and deposition on the lowlands may have reduced the region to an area of low relief.

In Nova Scotia the earliest deposit of the Windsor sea is commonly a finely laminated limestone. This earliest limestone was not seen at North mountain and, instead, at the few places where Windsor limestone may be seen resting on the crystalline rocks, the limestone is of a higher horizon, perhaps indicating that at North mountain the Windsor sea as it rose encroached upon an upland. The Windsor limestone and gypsum beds that floor at least the lower part of the valley in North mountain that opens on Little harbour, by their presence suggest that this valley was existing in Windsor time, but possibly the strata may owe their position to secondary folding along east-west axes and such folding may explain the attitude of the Windsor beds in the vicinity of Big Harbour post office. Thus, though the writer is inclined to believe that North mountain was an area of very considerable vertical relief during part or all of Windsor time, the available evidence is admittedly inconclusive and it may be that by Windsor time the uplands of Horton age had disappeared and that the general region was low and only gently undulatory. In any case it is not intended to suggest that the upland area of early Carboniferous time was necessarily as high or higher than that of today; nor to suggest that there has been no adjustment since Mississippian time. The dips of the sediments on both sides of the mountain certainly indicate strong movements since deposition.

After the close of Palæozoic sedimentation, the Carboniferous strata were folded and another cycle of erosion set in. During the Mesozoic era the greater part of the mainland of Nova Scotia and all of Cape Breton appear to have undergone erosion. The surface developed by this cycle is the Atlantic upland and is, by Goldthwait, correlated with a similar surface that is well developed along the Atlantic coast of the United States, where it is known as the "Cretaceous Peneplain". In Cape Breton, not only were the folded Carboniferous strata bevelled to a smooth surface, but the higher parts of the areas of crystalline rocks were also truncated, although on account of their resistant nature they may, perhaps, have projected above the general level.

North mountain, with its neighbours, Sporting mountain, Craignish hills, Mabou highland, and a small area on Madame island, are the remnants of the Atlantic upland in western Cape Breton. They rise more or less sharply from the lowlands surrounding them and increase in elevation from south to north. North mountain attains an elevation of a little more than 700 feet above sea-level, and its slightly undulating surface slopes gently to the north and west. A full view of the upland surface is generally masked by the thick forest growth, but where clearings give opportunity for wider vision the surface is seen to be monotonously regular, and to be unrelieved by any important elevations. From North mountain the Craignish hills to the north, and Sporting mountain to the south present even skylines, and it requires little imagination to visualize the original peneplain: the whole area near sea-level, the intervening valleys filled with

Carboniferous sediments, and a sluggish drainage system occupying the wide valleys of that time.

The drainage on the ancient surface has been fully discussed by Goldthwait,[1] but so far as North mountain is concerned, this area gives little if any clue to the ancient drainage development. There is no evidence that the harder rocks had more topographic relief than the areas of sediment, but doubtless at many places the crystalline areas acted to control the drainage courses.

After peneplanation had reached a development that must have been nearly a maximum, the region was uplifted and tilted to about its present position. This tilting extended over the whole region and appears to have taken place without any great dislocations. Because of the rising of the land surface the old drainage lines which were doubtless to the south and east and controlled no doubt by the areas of crystalline rock, were rejuvenated and commenced active erosion in their old channels. It is this third cycle of erosion that has formed the lowlands.

The effects of the third erosion cycle have been confined chiefly to the areas of Carboniferous strata that occupy the intervals between the crystalline areas. The later drainage has in these strata developed wide valleys which are accentuated by the resistant crystalline masses. The gradual erosion of the softer strata would also lead to erosion of the crystalline highlands.

The present lowland surfaces are more or less distinctly separated from each other by the crystalline hills. The lowlands may rise as much as 400 feet above sea-level. The rolling surface is in places interrupted by areas of strata which, through differing lithologic characters, are more resistant than usual and stand up as low hills.

The sinking of the surface, believed to have taken place before glaciation,[2] interrupted the normal erosive cycle in as far as the drowned parts of the country are concerned. Subsequent glaciation has modified the land surface and positive and negative movements of sea-level have taken place. In the vicinity of North mountain, the drowning of the former valleys is well illustrated in Denys basin and West bay, and the glacial modifications are shown by the hills of glacial till at the eastern end of the mountain, and along the south shore. The ice has also doubtless modified the lowland surface by smoothing the more elevated parts and filling in some of the valleys.

The melting and withdrawing of the ice-sheet in North America left large areas of country below the level of the sea and it was not until a considerable time had elapsed that the land regained in some measure its former position. Many authorities unite in stating that the line of zero post-Glacial uplift passes through Cape Breton. In the vicinity of North mountain, however, there are indications of a slight positive movement since the retreat of the ice. The clay at Eden siding, between River Denys and Orangedale, although not stratified, contains few pebbles, and may be water laid, as it is stated to overlie the glacial drift.[3] The

[1] Goldthwait, J. W.: Op. cit., pp. 40–48.
[2] Goldthwait, J. W.: Op. cit., pp. 4–5.
[3] Ries, H., and Keele, J.: "The Clay and Shale Deposits of Nova Scotia and Portions of New Brunswick"; Geol. Surv., Canada, Mem. 16, 164 pp., p. 64 (1911).

stratified clays and gravels, noted in the valley of Big brook, may also be of estuarine or marine origin, although no fossils were observed, and the shell layer, stated to lie near the bottom of the gravel deposit near River Denys, is also of value as evidence. The bottom of the gravel pit has an elevation of about 70 feet above sea-level.

## THE SHORELINE[1]

The shorelines of Bras d'Or lakes have been investigated by Tarr,[2] Woodman,[3, 4] Goldthwait,[5] and Johnson[6]. It appears to be well demonstrated that these lakes resulted from the drowning of former drainage systems, and that the irregular shore pattern is in the main due to original irregularities of the non-drowned surface rather than to erosion by marine agencies. According to Johnson,[7] shorelines of submergence may be divided into two classes; (a) those formed by the partial drowning of a land mass that has been dissected by normal river valleys (the ria shoreline); and (b) those formed by the partial drowning of a region of glacial troughs (the fjord shoreline). Although Cape Breton has been intensely glaciated, glacial troughs, of the over-steepened type characteristic of mountain regions, are uncommon, and the shoreline of Bras d'Or lakes falls into the first class, namely, the ria shoreline.

The chief agents in the shaping of a shoreline are waves and currents of several varieties that are produced in different ways.[8] In Bras d'Or lakes the connexion with the open sea is so restricted that ocean currents are non-existent, and, as the tidal range in the lakes is very small, currents caused by tides are negligible, except at the entrance where tidal currents in Great Bras d'Or channel may attain a velocity of 7 miles an hour. The shore forms produced are, therefore, the result of wave action, and of currents caused by wave action, and are thus indirectly controlled by the winds. At North mountain the greatest effects caused by wave action are to be seen at Malagawatchkt and Militia peninsulas and along the north shore of West bay where the expanse of open water is at a maximum. In Denys basin, wave-built forms are also developed, but since this water is more restricted, the forms are subordinate.

The greater part of the North Mountain shoreline is developed on the lowland areas which fringe the northeastern and southwestern ends of the crystalline area. Two groups of rocks occur on the lowlands, the sedimentary group of Carboniferous age, and the overlying unconsolidated deposits of glacial origin. Both of these groups take part in the shore forms developed, but the glacial deposits are by far the most important. The effect of the partly drowned glacial topography is to give an exceedingly irregular shoreline, with many bays, islands, peninsulas, and the dead

[1] Admiralty Chart, No. 2758, illustrates the features described in the following paragraphs.
[2] Tarr, R. S.: "Wave-Formed Cuspate Forelands"; Am. Geol., 22, pp. 1–12 (1898).
[3] Woodman, J. E.: "Shore Development on the Bras d'Or Lakes"; Am. Geol., 24, pp. 329–342 (1899)
[4] Woodman, J. E.: "Forelands on the Bras d'Or Lakes"; N.Y. Acad. Sc., Annals 22, p. 351, Abst. (1913).
[5] Goldthwait, J. W.: Op. cit., pp. 104–107.
[6] Johnson, D. W.: "The New England-Acadian Shoreline"; J. Wiley and Sons, N.Y., 608 pp. (1925).
[7] Johnson, D. W.: "Shore Processes and Shoreline Development"; J. Wiley and Sons, N.Y., 584 pp., pp. 173–186 (1919).
[8] Johnson, D. W.: "Shore Processes and Shoreline Development"; J. Wiley and Sons, N.Y., 1919, 584 pp., pp. 1–158.

waters which accompany them. This large amount of shoreline gives a greater opportunity for coastal erosion, but, on the other hand, the irrgularities and islands break up and restrict the bodies of water, and it would be difficult for the wind to form waves and currents of sufficient intensity to erode and transport the material were it not in an unconsolidated condition.

The Carboniferous sediments outcrop at only six places along the lowland shore, and even there the rock exposed is in four cases gypsiferous. Wherever gypsiferous strata are exposed, cliffs are prominent, and it appears as if the erosion of the soft strata was too rapid to permit solution to soften the cliff-like form. From the tops of many of the gypsum cliffs the land slopes downward away from the shore. This feature is due to the sink-hole topography so characteristic of land underlain by gypsum.

The unconsolidated glacial deposits, mantling the Carboniferous strata, give a variety of shore forms, for they suffer rapidly from erosion, and the materials are apparently transported with ease by waves and currents. For the most part the deposits are of boulder clay, consisting of a mixture of rounded crystalline boulders, with flatter sedimentary boulders and pebbles, in a clayey matrix. Without doubt the post-Glacial shoreline was much more irregular than the shoreline of today. Not only were small bays and inlets more numerous, but there were many more islands.

The effect of the wave action has been to form cliffs in the more exposed glacial deposits, to transport the eroded material along the base of the cliffs, and to deposit it at the first opportunity. Where the glacial deposits are in the most exposed positions, as at Malagawatchkt point, Pellier point, and the islands of West bay, the erosion has been at a maximum. The drumlin forming Malagawatchkt point is transverse to waves from the centre of the lake, and the material has apparently been transported in two directions, depending upon the direction of wave attack. This drumlin is tied to Malagawatchkt peninsula by two tombolos, one of which forms a baymouth bar at the entrance to Gillis pond. The material for this bar has been derived from the small, nearly destroyed drumlin to the southwest, as well as from the Malagawatchkt drumlin. The second tombolo appears to be the result of wave attack from the north, and very little if any material has come from the south. The recurved spit, at the eastern end of the Malagawatchkt drumlin, is in the main the result of wave attack from the south and west, with perhaps some attack by waves from the southeast. The Malagawatchkt drumlin, at the present time, is about half eroded parallel to its length, and presents a high cliff of glacial material on the southeast side, whereas the northwest slope is wooded and gently convex upward.

Pellier peninsula is made up of three drumlins, with the largest to the east. The peninsula originally consisted of two islands separated by a narrow, shallow channel. Wave attack from the northeast has caused a fusion of the islands by means of a tombolo, which in reality, because of the narrow, shallow separating channel, has been built as a baymouth bar. Pellier peninsula is tied to Militia peninsula by a tombolo resulting from the growing together of two cuspate bars. The lagoons enclosed by the original

bars may be seen at either end of the tombolo as marshy depressions. The material making up the recurved spit at the south end of Pellier peninsula has been derived from the largest drumlin by truncation at an angle to its main axis. This spit has apparently been built out into moderately deep water, as the writer was informed that schooners had been known to anchor within the hook. The effect of wave attack and transportation, even within the restricted Pellier harbour, is illustrated by the slight truncation at the south end of the two smaller drumlins, and the formation of a series of recurved spits at the western side of the harbour.

Where the glacial deposits were built on higher ground, and did not form islands, as at Militia peninsula and Malagawatchkt peninsula, the original shoreline was scalloped by many small bays. Wave attack on the headlands, and transportation along shore has now resulted in the formation of baymouth bars enclosing shallow, swampy lagoons, most of which have no connexion with the open water. Lagoons of this character may be seen on either side of Grammo point, and at several places on Militia peninsula. The transported material appears in every case to be derived from the immediately adjacent cliffs of glacial material, but characteristically it is made up of a relatively large proportion of sedimentary pebbles. It appears that the flat shape of these, in contrast with the more rounded pebbles of igneous origin, permits their being more easily transported.

The islands of West bay are exposed to waves from the east, southeast, south, and southwest, and show many examples of wave-built forms. The large, irregular peninsula, of which the point called George island is a part, is made up of at least seven drumlins, most of which were probably at one time islands. They are now connected by a series of pebbly tombolos, built of material eroded from the sides and ends. The innermost drumlins are exposed only to waves from the southwest and consequently are eroded to only a slight extent. Were the drumlins of Cameron island not so far removed from the George Island peninsula, these also might have been added to the assemblage. Tailor island and Crammond islands each consist of several drumlins. They differ from the other islands in that the low ground between the drumlins has not been submerged to any extent and consequently exhibits only baymouth bars built across the small scallops of the original shoreline. Two small, but perfect, recurved spits are developed at the south end of the channel between the Crammond islands. Each is built by the transverse erosion of a drumlin, and the direction of wave attack has apparently been from the southeast and southwest. Very good examples of double tombolos are to be seen at Clarke island, and the island to the southeast of Cow island. The latter two islands may eventually become joined through the growth of cuspate spits from each.

It is to be expected that, as wave attack proceeds, it will eventually carry away and disperse all the glacial material; and that in time the islands will have become entirely eroded, provided that no resistant rocks occur as cores in the drumlins. Examples of this process are to be seen at Magnus island, east of the village of West Bay, and at Ronald island (spelt 'Ranald' on Admiralty chart), southeast of Tailor island. Both islands are now quite small, but show traces of their former extent

in the shoal water that surrounds them, and in the number and size of the boulders that fringe the shore. Magnus island has evidently been attacked by waves coming directly from the east. It shows a small cliff facing east, at the bottom of which are many large boulders. From the top, the cliff slopes gently westward to the water-level.

The lowland between Ross brook and the village of West Bay is of very irregular outline, and has many baymouth bars enclosing lagoons between deposits of glacial material. The deep bays in the vicinity of Ross brook are evidently too restricted to permit wave action of any consequence, but on the southeast shore the glacial headlands are being energetically cut back and the material carried to the heads of the bays. Two long, curved spits are built by the transverse truncation of two drumlins on either side of Head Bay cove and their development restricts the channel leading to the village of West Bay.

That part of the crystalline mass of North mountain exposed to the waters of West bay, presents an entirely different class of shoreline. On the lowland, the shoreline is of irregular pattern, and is chiefly built up on the glacial deposits, with few occurrences of the Carboniferous strata; whereas the upland shoreline is comparatively straight, has few sharp indentations, and at several points the crystalline rocks outcrop at the water's edge. Where the crystalline rocks are exposed at the shoreline, they have been cut into cliffs which generally do not exceed 10 to 12 feet in height, but which may reach heights of 60 feet. The cliffs are as a rule steep, but wave-cut notches are not prominent.

The beach of the upland shore is composed almost wholly of pebbles and boulders of crystalline rock, many no doubt of glacial origin, but some derived from the rocks in the immediate vicinity. The material is coarser than that found in the glacial deposits, and, on that account, transportation by shore currents and waves is not prominent. Where the streams from North mountain have brought down finer material, and have built alluvial cones and fans near the shore, transportation has taken place, and as a consequence the mouths of some of the larger streams show small, cuspate bars enclosing marshy lagoons.

A certain amount of protection is given the south shore by the islands in West bay, and on that account erosion and transportation are perhaps not as great as they would normally be. An example of this is to be seen along the shore of Clarke cove, near Marble Mountain. This shore is well protected from the east and south, but is comparatively open to winds from the southwest. The quarrying operations at Marble Mountain have resulted in large dumps of broken rock that has reached the shore, and has been transported in an easterly direction as far as the hooked spit near the mouth of Mill brook. Because of the character of this material, a white, crystalline limestone, the amount of transportation may be clearly discerned. It was noted that none of the crushed rock had been transported to the west of the point where the rock dumps reach the shore. Farther to the west, in the vicinity of Lime Hill and towards Ross brook, transportation takes place in the opposition direction, namely, to the west.

The Carboniferous sediments at two points along the south shore are in contact with the crystalline rocks. At both places the dip is high, (about 70 degrees) and, therefore, is not an original structure. Faulting has undoubtedly taken place along the base of the mountain, but there is also evidence of a certain amount of upward drag of the early sedimentary beds during or after deposition.

The few outliers of Carboniferous sediment on the north slope of the mountain indicate that this slope is a resurrected and tilted surface of erosion; and it appears probable that the south slope is also, in part, of this character. In the absence of direct proof that the south scarp of North mountain is a fault-line scarp, it appears best to classify the south shore of the mountain as a resurrected peneplain shore-line, and since there are two erosion surfaces, one of which does not affect the form of the shore-line, it is of the morvan type.

## MINERAL RESOURCES

The minerals of economic importance in North Mountain district are limestones and gypsum, but up to the present time only the limestone has been worked. This rock is part of the George River series, and has a widespread occurrence, but a great deal of it is not favourably located for easy transportation. The gypsum occurs with anhydrite in the Windsor formation flanking North mountain, and evidences of gypsiferous formations are to be found at many points on the lowlands. At Maple brook, a small stream flowing into Big brook from the northwest, exposures of coal have been known for several years. Traces of metallic minerals are to be found at several points on North mountain, and some little work has been done in connexion with these occurrences, but the results obtained appear to have discouraged any extensive exploration.

### LIMESTONES

The limestones of the George River series, where developed in quantity and favourably situated, as at Marble Mountain, have been worked for lime, building stone, and metallurgical flux for about fifty years. The centre of the industry was on the shore of West bay, where close proximity to the water gave cheap and easy transportation. The value of the rock in this locality was first realized in 1861 [1, 2], but although limestone was no doubt quarried for local use by the early settlers, it was not until 1873 that the rock was extracted on a commercial scale, [3] when 8,000 barrels of quicklime were produced.

In 1888 the Bras d'Or Lime Company was incorporated to manufacture quicklime, and also to quarry marble for building purposes.[4] This company continued in operation until about the year 1900. About 1899 the Dominion Iron and Steel Company acquired property at Marble Mountain,

[1] Honeyman, D.: "Record of Observations on Nova Scotian Geology Since 1855"; N.S. Inst. Nat. Sc., Pr. Tr., 3, pp. 6–18, 18–40, p. 10 (1871–74).
[2] Fletcher, H.: "Report of Explorations and Surveys in Cape Breton, Nova Scotia"; Geol. Surv., Canada, Rept. of Prog. 1877–78, pt. F, 32 pp.
[3] Province of Nova Scotia, Rept. of Dept. of Mines, 1875, p. 69.
[4] "Mining and Metallurgical Industries of Canada"; Mines Branch, Dept. of Mines, Canada, 2 vols., 972 pp., p. 918 (1907–08).

and shortly afterwards started shipping limestone to the iron furnaces at Sydney, distant about 60 miles by water. Operations were carried on by this company until the year 1922 when work was discontinued and the quarry abandoned. The quarry was worked by benching and the rock was broken by dynamite. The early drilling was done by hand, but later steam drills, and still later air drills were used. The broken rock was trammed from the face in horse-drawn cars, and after being crushed was screened through trommels. From an inspection of the screenings, all sizes passing through a 2-inch ring were rejected. The oversize was conveyed by gravity to bins near the shore, from whence it was loaded into steamers for conveyance to Sydney. During the war, from 600 to 700 men were employed at the quarry. When production was at a maximum, two 10-hour shifts were worked each day. The greatest production was in 1915 when 399,407 tons of crushed rock were shipped.[1]

The quarry is situated on the southeast slope of North mountain, and above the village of Marble Mountain. It consists of two pits, one above the other. The limestones are in contact with the quartzites of the George River series exposed on the northwest side of the large pit and on the south side of the smaller pit. Lime silicates with quartz, olivine, serpentine, and specks of sulphides, occur on the northeast edge of the smaller pit, and apparently indicate that igneous rocks are close at hand.

Two varieties of limestone occur. The first, which is in greatest quantity, is a coarse white rock with no structures. The second, also coarse, is grey with distinct banding. Calcite veinlets and stringers are common in the grey variety. The relations between the two varieties are obscured by broken rock, faults, and folds, but it appears that they grade one into the other.

Analyses of the limestone are given below:

| — | (1) | (2) | (3) |
|---|---|---|---|
| $SiO_2$ | 2·58 | 0·90 | 2·54 |
| Iron oxide and $Al_2O_3$ | | | 2·12 |
| $CaCO_3$ | 88·67 | 96·31 CaO | 50·07 |
| $MgCO_3$ | 7·89 | 0·83 MgO | 3·06 |
| Sulphur | 0·00 | 0·01 | 0·086 |

(1) Rept. of the Director, Geol. Surv., Canada, Ann. Rept., vol. VIII, 1895, pt. A, p. 110A (1897). Average of ten analyses.
(2) "Mining and Metallurgical Industries of Canada"; Mines Branch, Dept. of Mines, Canada, 2 vols., 972 pp., p. 918 (1907–08).
(3) Dominion Iron and Steel Company. Average analyses 1911–20.

[1] For these historical data the writer is indebted to the Dominion Iron and Steel Company, and to Mr. A. C. Campbell of Marble Mountain, who was an employee at the quarry for over twenty-five years.

Tests made on the stone with regard to its structural characteristics are as follows:

| | |
|---|---|
| Specific gravity[1] | 2·72 |
| Weight per cubic foot | 169·5 pounds |
| Pore space | 0·087 |
| Ratio of absorption | 0·032 |
| Coeff. of saturation, 1 hour | 0·87 |
| " " 2 " | 1·00 |
| Crushing strength | 18,197 lbs. per sq. in. |
| " dry after freezing | 16,148 " " |

The limestone as exposed at the present time is not suitable for a structural stone, as it is badly shattered and broken. A very fissile structure is also present at some points, and several faults were noted on the quarry face. The explosives used when the quarry was worked for metallurgical flux were no doubt the cause of much of the fracturing.

Although apparently limited to the north, the rock in this vicinity is by no means exhausted, and further exposures of limestone occur to the south and west of the quarry. A diamond-drill core, stated to have come from a point 247 feet below the floor of the main pit, consists of a pure white crystalline rock apparently free from close fracturing.

At several other points on North mountain, limestone occurs in greater or less quantity. West of Little Harbour, the hillslope below the bare bluff known as "The Creigan," has many outcrops of a contorted, blue-weathering limestone. A small quarry near the shore has been driven in a well-bedded limestone which is associated with graphitic shales.

The lakes at the head of Mill brook, east of Marble Mountain, are in an area of numerous limestone outcrops. The extent, however, is not believed to be great, as granite occurs nearby and apparently surrounds the individual outcrops. Relations similar to these are to be found in the area west of Sydenham brook, on the farm of Mr. Christopher McRae. Several pits opened in this rock show it to be coarsely crystalline, and white when freshly broken, but turning a bluish colour on weathering. Granite outcrops occur in the immediate vicinity, and in the gorge of Sydenham brook the granite extends nearly to the shore. Through the courtesy of Mr. George McKenzie, of Marble Mountain, the writer was permitted to examine a small map of this property that had been made for the Bras d'Or Lime Company about the year 1902. An analysis given on the map was as follows:

| | Per cent |
|---|---|
| $SiO_2$ | 0·66 |
| $Fe_2O_3$ | 0·74 |
| $Al_2O_3$ | 1·45 |
| $CaCO_3$ | 59·50 |
| $MgCO_3$ | 37·80 |
| Sulphur | 0·06 |

West of Marble Mountain, several small quarries have been opened close to the road, but in none of these does the extent of the limestone appear to be very great. North of Lime Hill, at McMillan's farm, blue-weathering limestones are well exposed. Further exposures are present on the ridge to the east of Campbell brook, and strike towards River

[1] Parks, W. A.: "Report on the Building and Ornamental Stones of Canada"; Mines Branch, Dept. of Mines, Canada, 2 vols., p. 178 (1914).

Denys, where a considerable development is found on McLeod's farm. This rock is banded, of various colours, but is invariably coarse grained. It occurs in a belt about 1,000 feet wide, but is possibly interbedded with other members of the George River series. The limestone belt is bordered on the southwest by the volcanic series, and on the northeast by the quartzites. From appearances this is an extensive occurrence, but it has not the advantage of being close to the water, as have those on the south side of the mountain.

### GYPSUM

Gypsum and anhydrite occur at many points within the area mapped, but are most abundant towards the eastern end of the mountain, and no outcrops of these minerals were noted southwest of River Denys on the northwest, and Crammond islands on the southeast. The exposures are not confined to the areas adjacent to the crystalline rocks where the Carboniferous strata are turned up against the former, but may be seen at other points on the lowland where the gypsiferous strata are brought to the surface by folds.

In the neighbourhood of River Denys there are several indications of gypsum, but the exposures are neither abundant nor large. Three small outcrops of a white, fine-grained, and finely laminated rock are to be seen in a railway cut about $\frac{1}{2}$ to $\frac{3}{4}$ of a mile east of the station. The rocks dip about 30 degrees northeast. Other indications were observed south of Denys river near Munroes Bridge where cliffs of gypsum skirt the river bank east of the bridge. This belt trends eastward across the small peninsula, and its extension is indicated by sink-holes on the farm of Mr. L. McLean near South Side Basin of River Denys. Other sink-holes occur in the lower part of the valley of McKenzie brook, and the small lakes at this place may be due to water-filled sink-holes. Plaster island, between South Side Basin of River Denys and Plaster cove, exhibits cliffs of gypsum and anhydrite.

The gypsum to the east of Munroes Bridge occurs on three farms, owned respectively by Messrs. Alan McLean, John McLean, and Malcolm McLean. The cliffs on the farm of the former show the greatest quantity observed in the vicinity. The exposures extend along the water's edge for over a quarter mile, and the cliffs rise in places to heights of 40 or 50 feet. The point of the peninsula is occupied by a sandy, oolitic dolomite, which from its position near the water's edge is believed to underlie the gypsum. Small layers of grey, fine-grained, unfossiliferous limestone, up to 6 inches in thickness, occur within the gypsum. Three such layers were noted on one face. Grey clayey material is also intercalated with the gypsum at some places, and appears to increase towards the top and bottom of the exposures. At some points, large, oval, or pillow-shaped masses of clay lie within the gypsum whose bedding planes curve around the oval masses. The ground at the top of the cliffs, as is common in such localities, is pitted with sink-holes and depressions. These extend across the peninsula to the farm of Malcolm McLean, where the gypsum is again exposed, and is underlain by a dark grey, fossiliferous limestone. No anhydrite was observed in any of these exposures, and the gypsum,

varying between compact and granular, is of fair quality. Due to the inactiveness of foreign material, which is not carried off when the gypsum dissolves, the exposed surfaces appear to carry more impurities than is actually the case. An analysis from the locality, given by Jennison,[1] is as follows:

| | Per cent |
|---|---|
| Lime | 33·17 |
| Sulphuric anhydride | 45·42 |
| Water, loss on ignition | 20·63 |
| Insoluble mineral matter | 0·93 |

Few exposures of gypsum are to be found along the belt of sink-holes that trends towards the valley of McKenzie brook, but a considerable area appears to be underlain by these rocks. Plaster island, the promontory east of South Side Basin of River Denys, is mainly composed of gypsiferous strata. The cliffs exhibit alternating bands of anhydrite and gypsum, in the proportion of about 3 to 2. Small veinlets of gypsum cut the anhydrite layers. From the top of the cliffs the strata dip rather steeply northward, and at the north side of the peninsula the proportion of gypsum increases over the anhydrite. The rock is grey-white and coarsely granular.

Boom island, the large island at the eastern end of Denys basin (*See* Fletcher's map), has several exposures of gypsum along its north shore. The cliffs in this case are not high, and many of the exposures are obscured by slumping. Although anhydrite was not noted, the gypsum varies considerably in quality, being in many cases mixed with nodules of limy clay. Some of the material is of alabaster quality, of medium grain with a slight tinge of pink. Grey-green rosettes of selenite are common in some of the gypsum layers. They grow in a matrix of white, fine-grained gypsum.

Two exposures of gypsum occur at Grammo point. The outcrop extends along the shore for about 600 feet and dips to the northeast beneath the water. The gypsum extends downward into a limy clay, and like that at Boom island is characterized by rosettes of selenite in a groundmass of white gypsum.

Near Big Harbour post office, gypsiferous strata occur in a belt running parallel to the road, and near the contact of the sediments on the crystalline rocks. The strata are exposed on the farms of Messrs. D. J. McKinnon, L. McKinnon, J. M. McKenzie, C. McLean, and Mrs. Donald McKinnon. The most southerly exposures, on the farm of D. J. McKinnon, show from 40 to 50 feet in section, but they may not be traced laterally for any distance. One section consists mainly of anhydrite, becoming gypsiferous towards the top, and showing the change to gypsum with the development of cracks. The second exposure shows a coarse grey gypsum, irregularly banded, and with only minor quantities of anhydrite. A little to the north, and directly behind Big Harbour post office, a rather extensive exposure of gypsiferous strata trends northeastward along the bank of a small stream. The strata form a small cuesta with the gentle slope to the northeast. The main mass of the exposure consists of anhydrite

[1] Jennison, W. F.: "Report on the Gypsum Deposits of the Maritime Provinces"; Mines Branch, Dept. of Mines, Canada, 171 pp., p. 50 (1911).

trending laterally up the face of the cuesta. Exposed sections show from 30 to 50 feet of anhydrite capped by varying thicknesses of banded gypsum. The gypsum in places grades into the anhydrite and in other places is sharply separated from it. The dip of these strata is to the northeast, and they may be an extension of the beds outcropping at Grammo point. In this particular area none of the associated rocks, either above or below the gypsum, were noted.

The embayment of the Carboniferous strata in the valley of the stream running into Little harbour also contains gypsiferous strata. The exposures in this locality, however, are small, and the rocks are masked by drift and stream wash.

### OTHER MINERALS

The George River series, where it is closely associated with the intrusive igneous rocks, may carry various sulphides, and in some cases graphite. Although no large bodies of sulphide were noted, and none of the occurrences is believed to be of economic importance, their recognition is worthy of note. At a point on the road, immediately to the east of Mill brook, a slight, local deviation of the compass needle was very marked.

A small showing of pyrite and sphalerite occurs about half-way between Lime Hill and Ross brook, on the farm of Mr. D. Campbell. The sulphides, and the enclosing rock, apparently a metamorphosed limestone, are exposed in one small pit that was opened by Mr. Campbell several years ago.

The zone of mixed rocks between West Bay Road and Big Brook post office contains a few small areas of limestone associated with schists and igneous rocks. One of these areas, on an abandoned farm near the top of the mountain, shows graphite-bearing rock exposed in two pits, 10 feet deep and 475 feet apart. The pits are said to have been opened about twenty-five years ago. The graphitic rock is schistose, iron stained, and shows much crumpling. It is in close association with a limestone carrying garnets and serpentine.

The dark slates occurring at the fault zone west of Little harbour, in the upper part of Campbell brook, and again lower in the brook, contain small lenses and streaks of pyrite following the foliation of the slate. As a general rule the rocks are sheared along this zone, and have a brilliant lustre on the schistose surfaces. Gold is said to occur in this zone on the lower part of the brook, and some years ago a tunnel (now caved) was driven into the hillside. The rocks are cut by anastomosing and strike veinlets of carbonate.

Farther up Campbell brook the other members of the George River series carry pyrite, associated with quartz, in irregular streaks and bands. Carbonate veinlets also cut these rocks. Although pyrite was the only sulphide noted in this locality, pebbles in the stream bed, when wholly or in part composed of lime carbonate, were seen to have the latter crusted with a thin coating of green copper carbonate.

## VITA

Tarrant Dickie Guernsey

St. Marys, Ontario, Canada, September 21, 1897

Member, Canadian Expenditionary Forces, World War

University of British Columbia, 1919-1924

B.A.Sc. (Metallurgy), 1923

Columbia University, 1924-1927

University Scholar, 1924-1925

Kemp Fellow, 1925-1926

Sigma Xi, 1925

Assistant, Columbia University, 1926-1927

Field Assistant, Geological Survey of Canada, 1921, 1922, 1923, 1925

Geologist, Anglo-American Corporation of South Africa, Ltd.

OTTAWA
F. A. ACLAND
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
1928